

The use of additional filler wire to solve the tandem GMAW issues

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Abstract. A review of the studies showed that the existing technologies for tandem gas metal arc welding (GMAW) of butt welds have a number of problems that do not allow to increase productivity while maintaining low heat input to base material and stability of the welding process. The possible solution of this problem by feeding of additional filler wire (AFW) in between the welding electrodes is researched in this study. Influence of addition of AFW into the arc and into the weld pool for single-arc GMAW on deposition rate and geometric properties of the welds are researched and the main problems of these methods are showed in the study. The effect of addition of AFW on the temperature of weld pool and heat input to base metal and solidification rate of the weld pool are showed in the study too. The main disadvantages of using pulsed welding modes for providing the stability of tandem welding process are described and the addition of AFW in between the welding electrodes for stabilization of trailing arc is justified. It is concluded that the further complex studies of effects of AFW on tandem GMAW are needed.

1. Introduction

Recently an increase in the productivity of welding processes only by increasing the specific heat input became non optimal, since this leads to deterioration in the weld metal formation and deterioration in the mechanical properties of the heat affected zone (HAZ). Moreover, the limitation of the specific heat input in favor of increase in the welding speed leads to reduction of the cross-sectional area of welds and, accordingly, to increase in the number of passes, lower productivity and an increased risk of defect formation [1].

To solve the problems encountered in various areas of welding production, multi-wire welding methods are widely used [2]. One of the most common methods of multi-wire welding is tandem gas metal arc welding (GMAW), which is actively used in the manufacture of ship panels, mining equipment and in bridge building and allows to achieve high process performance and reduce heat input to the base metal, on the one hand, due to the increased deposition rate, and on the other, due to an increase in welding speed, in some cases more than doubled.

A distinctive feature of tandem welding is the use of welding wires isolated from each other, which are fed through separate feeding mechanisms. The wires should be powered from separate welding sources [3], and during the welding process, control of the arcs can be carried out independently [3] or according to a certain control scheme. Due to this, it is possible to set the mode parameters for each wire separately, which allows to configure the welding arcs for various tasks. The most common



option is to use a main arc to ensure the required penetration depth and to set the geometric characteristics of the weld pool, and the trailing arc in order to ensure the maximum melting coefficient, while maintaining high quality of the weld surface, avoiding increased spatter [4], and also create the optimum temperature field in the weld pool, for improving the geometric characteristics and structure of the weld metal [5].

The main problems of this welding method are the insufficient productivity of the welding process compared to other multi-wire methods, the increased heat input to the base metal compared to single-arc welding, and the insufficient stability of the welding process. One of the solutions to these problems may be the use of an additional filler wire (AFW).

2. The use of AFW to increase productivity

In various studies, the use of AFW is often considered as a means of increasing the deposition rate, as well as influencing the geometric properties of welds. Typically, single-arc GMAW methods with AFW feed either into the arc [6] or into the weld pool are investigated.

2.1. The addition of AFW into the arc

The schematic of the method of welding with the addition of AFW into the arc is presented in Figure 1. According to the researches [7, 8], when feeding AFW into the arc, it becomes possible to increase the deposition rate by 100–140% compared to single-arc welding.

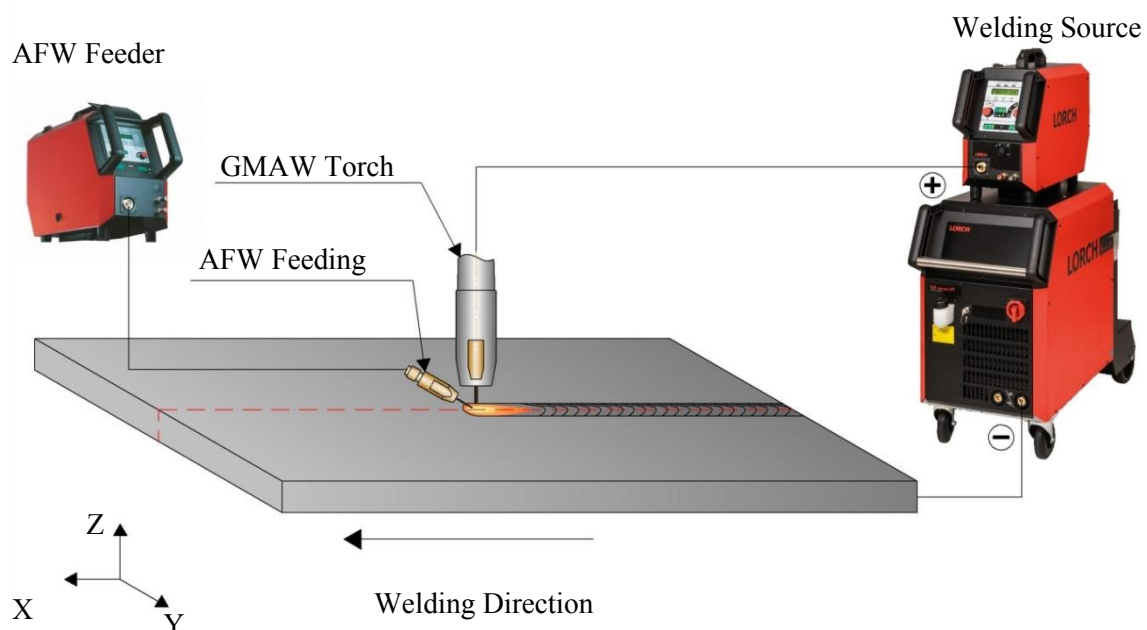


Figure 1. The method of welding with the addition of AFW to the welding arc [7].

The main problem of this welding method is low stability of the welding arc and increased spatter [7] with volumes of feed of the AFW from 60 to 80% of the supply volume of the welding wire. The solution to this problem is to further increase the relative feeding volume of the AFW. In this case, the arc completely passes to the AFW instead of the base metal due to the fact that the arc tends to flow along the path of the lowest resistance [7, 9]. A schematic of the arc transition to the surface of the AFW is presented in Figure 2.

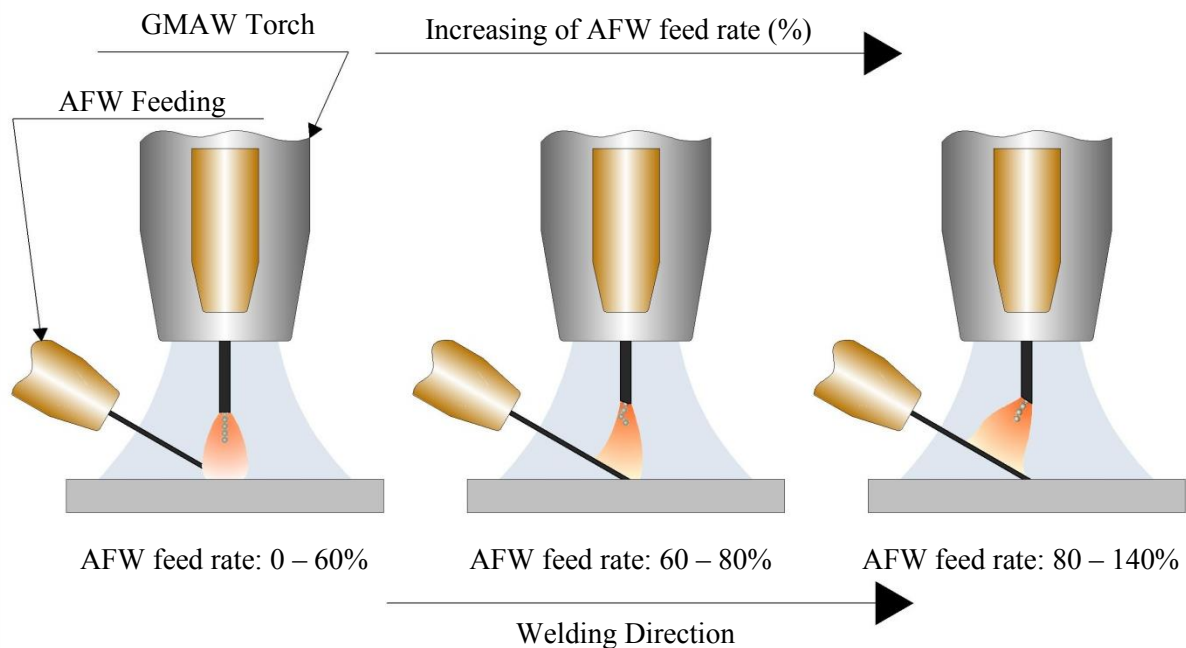


Figure 2. A schematic of the arc transition to the surface of the AFW with an increase in the volume of its supply.

However, with an increase in the AFW feed speed, the problem of reducing the penetration by half arises: the penetration values reduce from 2 mm to 1 mm at a current of 250 A, and from 3 mm to 1.5 mm at a current of 350 A, due to the deviation of the welding arc, and also the displacement of the cathode spot to the surface above the surface of the base metal, which reduces the pressure of the arc on the base metal. The percentage of inclusion of the base metal also decreases from 45% to 10% when welding at a current of 250 A and from 43% to 15% when welding at a current of 350 A [8]. Based on the obtained research results, we can conclude that this welding method is suitable for surfacing of large volumes of metal with small penetration.

2.2. The addition of AFW into the weld pool

Since the ability of the weld pool to melt the AFW is lower than that of the welding arc, the method in which the AFW is supplied into the weld pool is not characterized by high deposition rate and, accordingly, by different geometric characteristics of the weld pool [1]. So, the maximum achievable deposition rate is 50%. With a further increase in the volume of addition of AFW to the weld pool, periodic non-melting and jamming of the AFW in the crystallized weld pool can be observed [8].

The main advantage of this method in comparison with the method of feeding AFW to the welding arc is the absence of a significant reduction in the penetration depth [10].

The schematic of this welding procedure is presented in Figure 3.

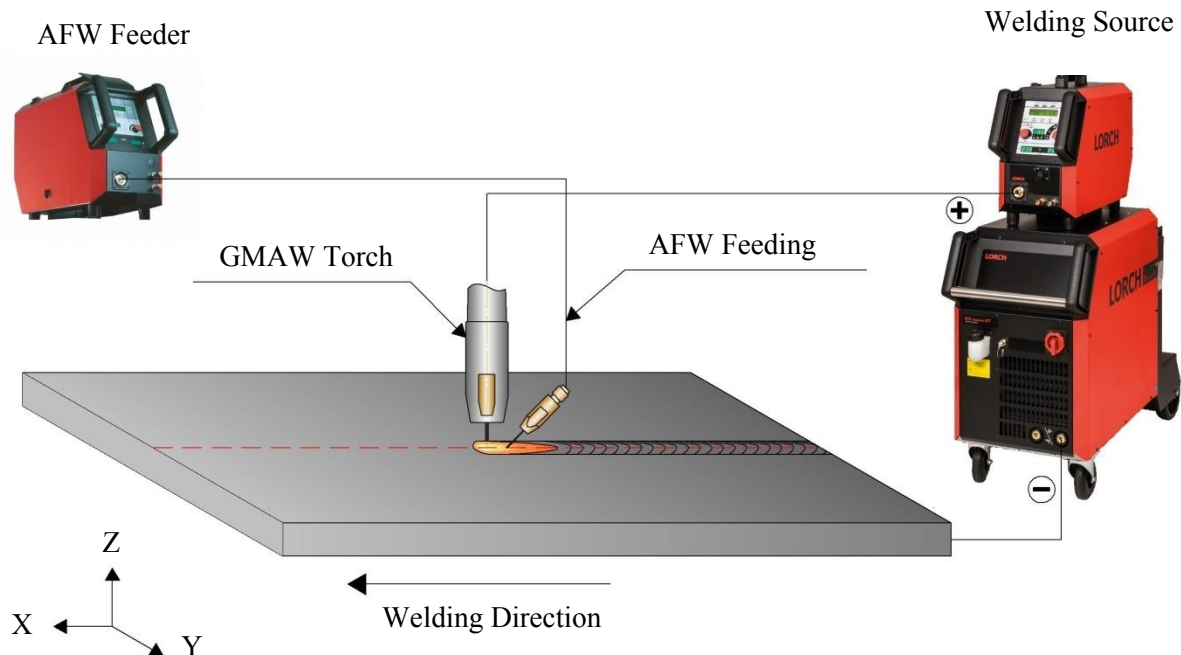


Figure 3. The schematic of the welding method with the addition of AFW into the weld pool.

3. The effect of AFW on heat input

The main reason for the decrease of welds quality during welding without AFW, is most commonly considered to be overheating of the metal of the weld pool and HAZ due to high heat input [1, 10–12].

According to the study [11], the addition of AFW into the arc leads to decrease of the weld pool temperature. The addition of AFW allowed reducing of the maximum temperature recorded by thermocouples from about 1550 °C to about 1400 °C when feeding the AFW to the welding wire in a volume ratio of 1 to 1.

A decrease in the temperature of the weld pool is also indicated by a decrease in its thermal influence on the base metal. As a result of the research [12], a decrease in the width of the coarsened grain zone in the HAZ to 50% was observed when butt welds were welded by GMAW with AFW as compared to the values obtained by GMAW without AFW [12]. The results of study [10] showed that addition of AFW with a volume of 50% of the volume of the welding wire into the weld pool decreases the angular distortion of the workpiece from 3.28° to 2.82°, which also indicates a decrease in heat input from the weld pool to the base metal.

Also, it is possible to influence the cooling rate of the weld pool depending on the place of the addition of AFW without changing the volume of added AFW. So, in the study [13], it is argued that the closer the AFW is added to the solidification zone, the smaller volume is required to increase the solidification rate. As the AFW approaches the welding arc, the melting rate of the AFW increases and the solidification rate decreases. As a result, due to a change of the AFW feed location, it is possible to control the cooling rate of the weld pool and thus influence the mechanical properties of the welding joint.

4. The main disadvantages of using pulsed welding modes

The stability of the tandem welding process should be determined by the ability of the welding arc not to be interrupted due to the magnetic influence of the arc nearby [14], not to violate gas shield quality due to periodic arc deviations [15], not to be oscillated between the filler and base metal. Low stability of the process leads to increased spatter, as well as instable weld pool formation [14, 16].

At present, the main research devoted to the leveling of the magnetic interaction of arcs are considered using pulsed welding modes as a solution to the problem. The most stable is the process in

which pulses are provided synchronously and with a minimum phase difference. With an increase in the phase difference of the pulses, the number of interruptions of one of the arcs increases, which leads to an unstable seam width, increased spatter, and violation of gas shield quality [15, 17]. Studies in which more complex configurations of pulses are researched [18, 19] are contradictory and cannot be used unquestionably.

Pulse welding with synchronous pulses and with a small phase difference has a number of significant disadvantages and limitations. Thus, a stable welding process can be achieved only if the welding currents of both arcs are approximately equal, and if an increase in heat input into the base metal is allowed with a decrease in the penetration depth and an increase in the weld width [15].

5. The main conclusions and lines for further research

If it is necessary to ensure a large penetration depth with a high deposition rate and low heat input into the base metal, as well as to stabilize the tandem GMAW process, AFW feeding in between the welding wires can be used. With this welding method, a significant decrease in the penetration depth under the first arc should not be observed, as well as a significant increase in the deposition coefficient due to the influence of the heat of the second arc on the AFW. The arrangement of the wires and tandem GMAW process with AFW is shown in Figure 4.

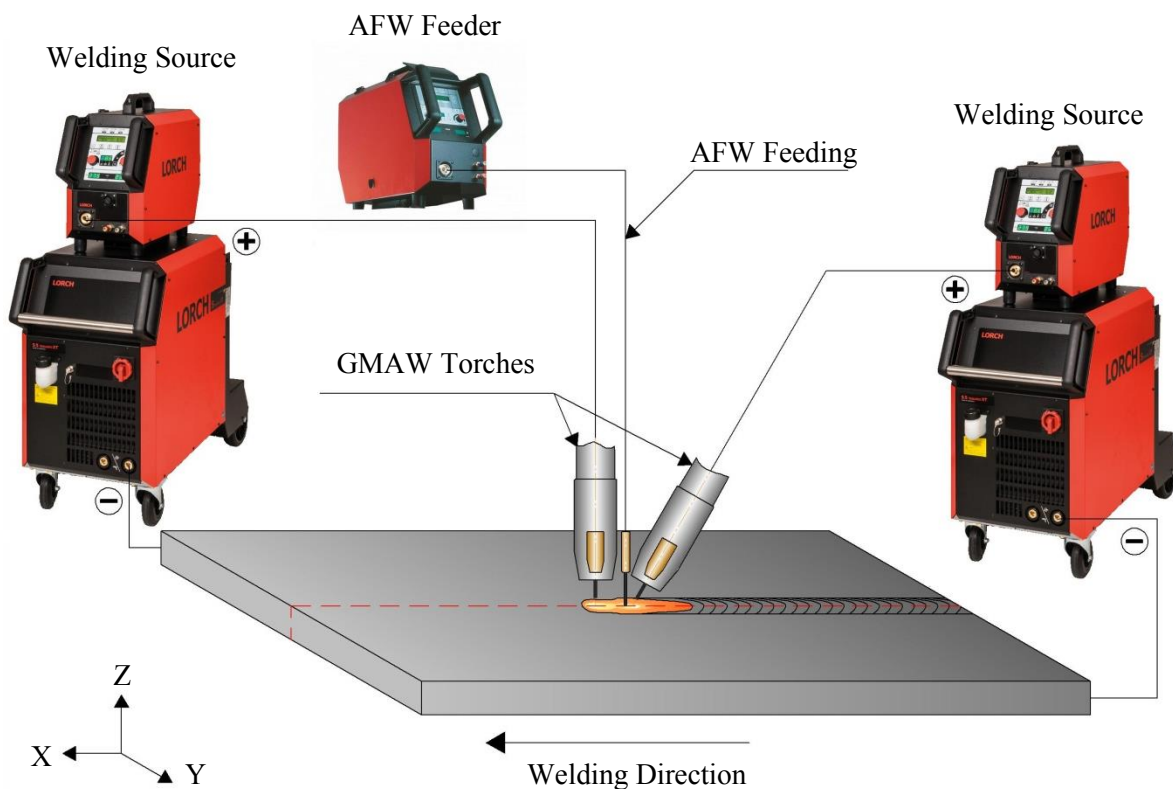


Figure 4. The arrangement of the wires and tandem GMAW process with AFW.

According to a few studies [20], an increase in the feed rate of the AFW to the weld pool, leads to stabilization of the cathode spot on the surface of the weld pool due to its constant cooling and liquid metal flow interruption at the location of the AFW feed. Thus, it becomes possible to stabilize the trailing arc and prevent its oscillations and interruption due to magnetic interactions, as well as to increase the deposition rate due to the heating of the AFW by the trailing arc. Existing studies of this phenomenon cannot provide a fuller picture, since they were carried out under conditions in which the AFW was added to the weld pool tail, at a great distance from both arcs, and studies of tandem

welding with the addition of AFW in between welding wires in order to stabilize the welding process has not yet been carried out.

Thus, further studies should be aimed at a comprehensive research of the tandem GMAW process with the addition of the AFW between the welding wires in order to determine the applicability of this welding method in industrial production, as well as to possibly eliminate the use of pulsed modes and simplify the control of the welding process.

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